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(71) Applicant(s)
Motorola Israel Limited

(Incorporated in Israel)

16 Kremenetski Street, Tel Aviv 67899, Israel

(72) Inventor(s)
Gadi Shirazi
Tal Mor
Zami Schwartzman

(74) Agent and/or Address for Service
Hugh Christopher Dunlop
Motorola Limited, European Intellectual Property Operation, Jays Close, Viables Industrial Estate, BASINGSTOKE, Hampshire, RG22 4PD, United Kingdom

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GB 2213663 A GB 2191367 A GB 2017436 A

(58) Field of Search
UK CL (Edition L) **H3A AD AN**
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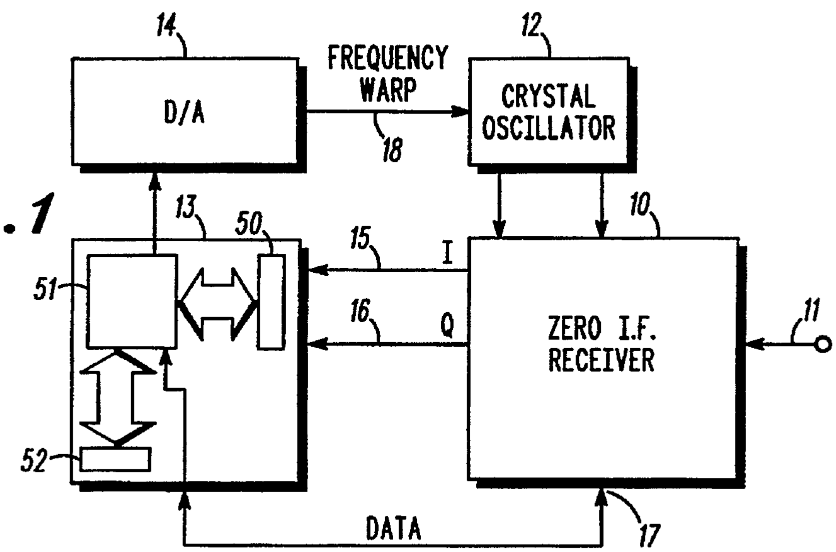
(54) **A radio device**

(57) A radio device, such as a radio receiver or a radio transceiver is described. An adjustable reference oscillator (12) provides a reference frequency signal and a direct conversion receiver stage (10) mixes a signal derived from the reference frequency signal with an input radio frequency signal, to directly convert the radio frequency signal to baseband at an output. Automatic frequency control (13, 14, 18) is implemented to adjust the reference oscillator to closely provide the desired reference frequency signal. A single-frequency radio transponder is also described comprising: a direct conversion receiver circuit (10) having an oscillator; a resonator for providing resonance for the oscillator and an automatic frequency control circuit (13, 14, 18) for controlling the oscillator and resonator. A micro-controller 13 measures the intervals between successive transitions of an in-phase output I to provide frequency control voltage. Alternatively a baseband output data 17 and a synchronisation word stored in memory 52 may be used. The receiver may be used in paging arrangements and control of sprinkler valve in irrigation.

FIG.1



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

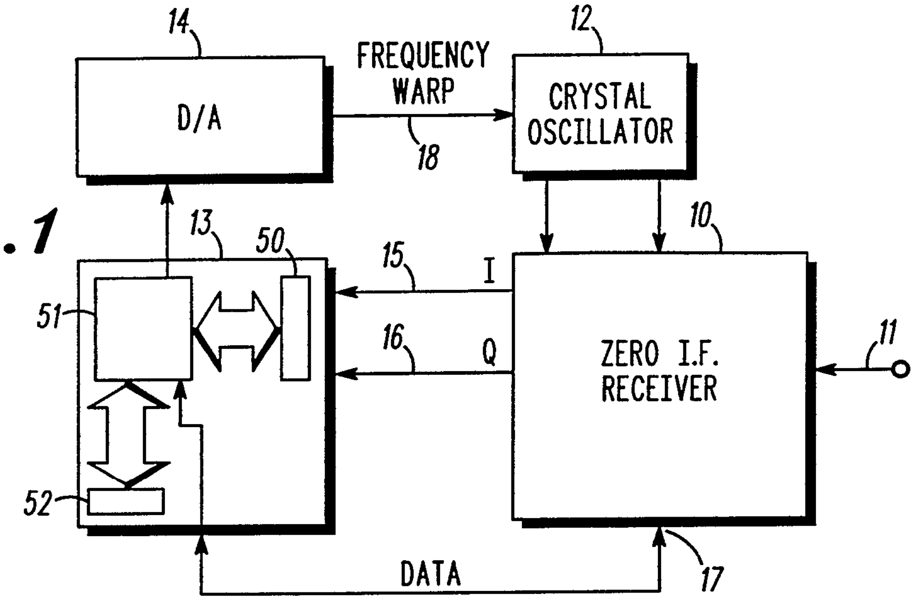

14
D/A
FREQUENCY
WARP
18
12
CRYSTAL
OSCILLATOR
10
13
50
15
I
51
16
Q
ZERO I.F.
RECEIVER
11
52
DATA
17

FIG.1

FIG.2

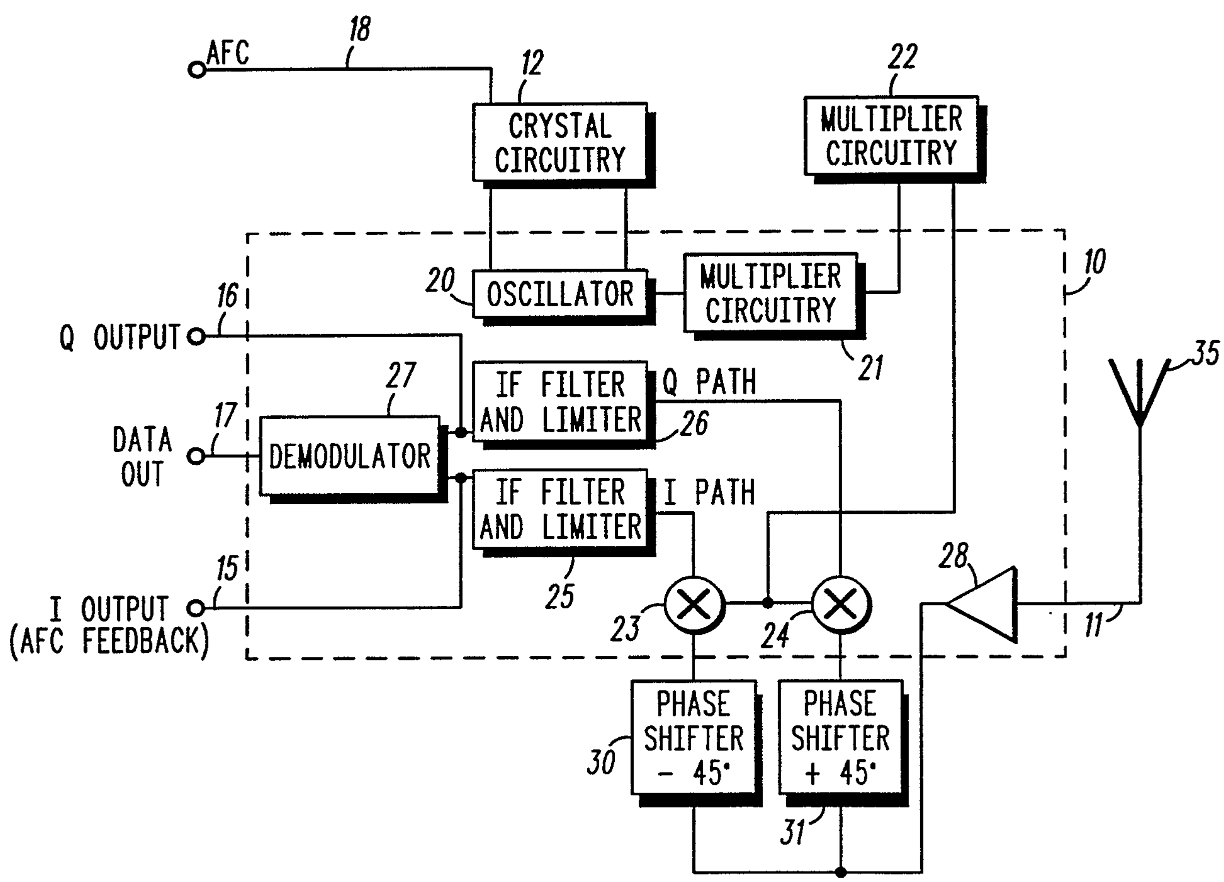

AFC
18
12
CRYSTAL
CIRCUITRY
22
MULTIPLIER
CIRCUITRY
10
20
OSCILLATOR
MULTIPLIER
CIRCUITRY
21
16
Q OUTPUT
27
IF FILTER
AND LIMITER
Q PATH
26
35
17
DATA
OUT
DEMODULATOR
IF FILTER
AND LIMITER
I PATH
28
15
25
I OUTPUT
(AFC FEEDBACK)
23
24
11
PHASE
SHIFTER
- 45°
PHASE
SHIFTER
+ 45°
30
31

FIG.3

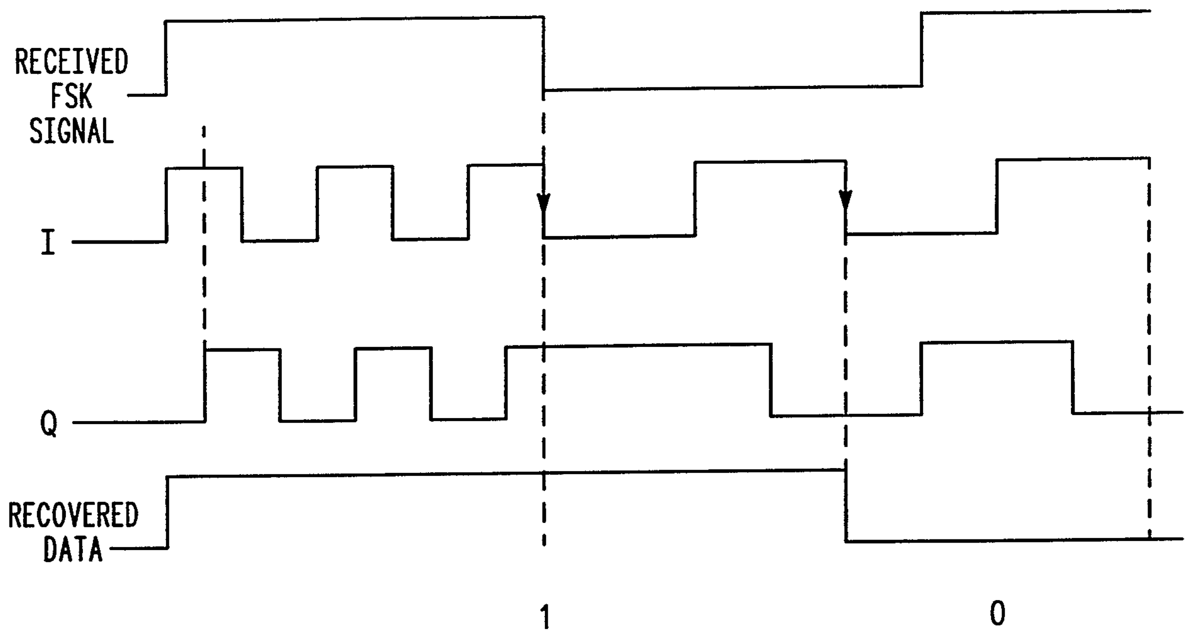
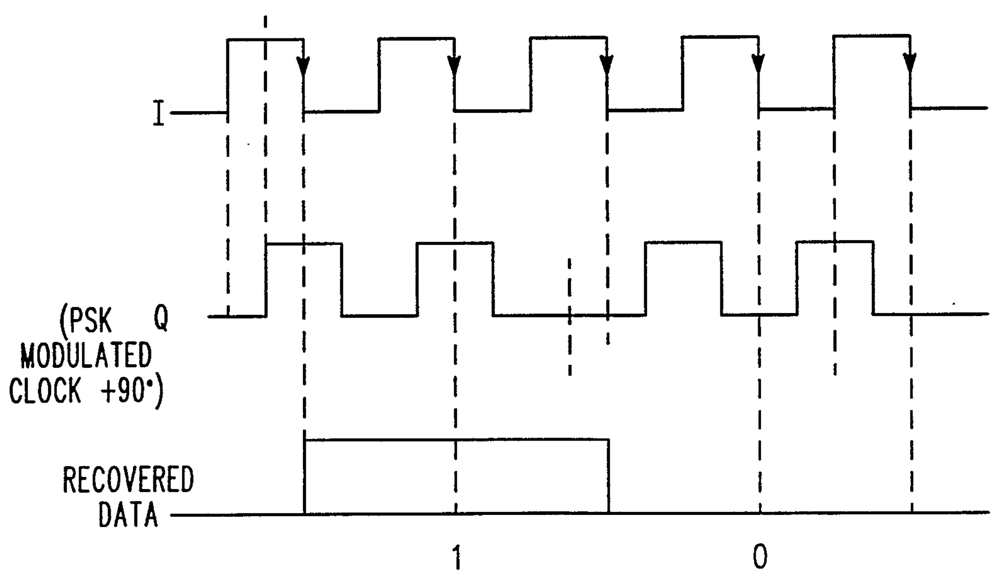

RECEIVED
FSK
SIGNAL
I
Q
RECOVERED
DATA
1
0

FIG.4


I
(PSK Q
MODULATED
CLOCK +90°)
RECOVERED
DATA
1
0

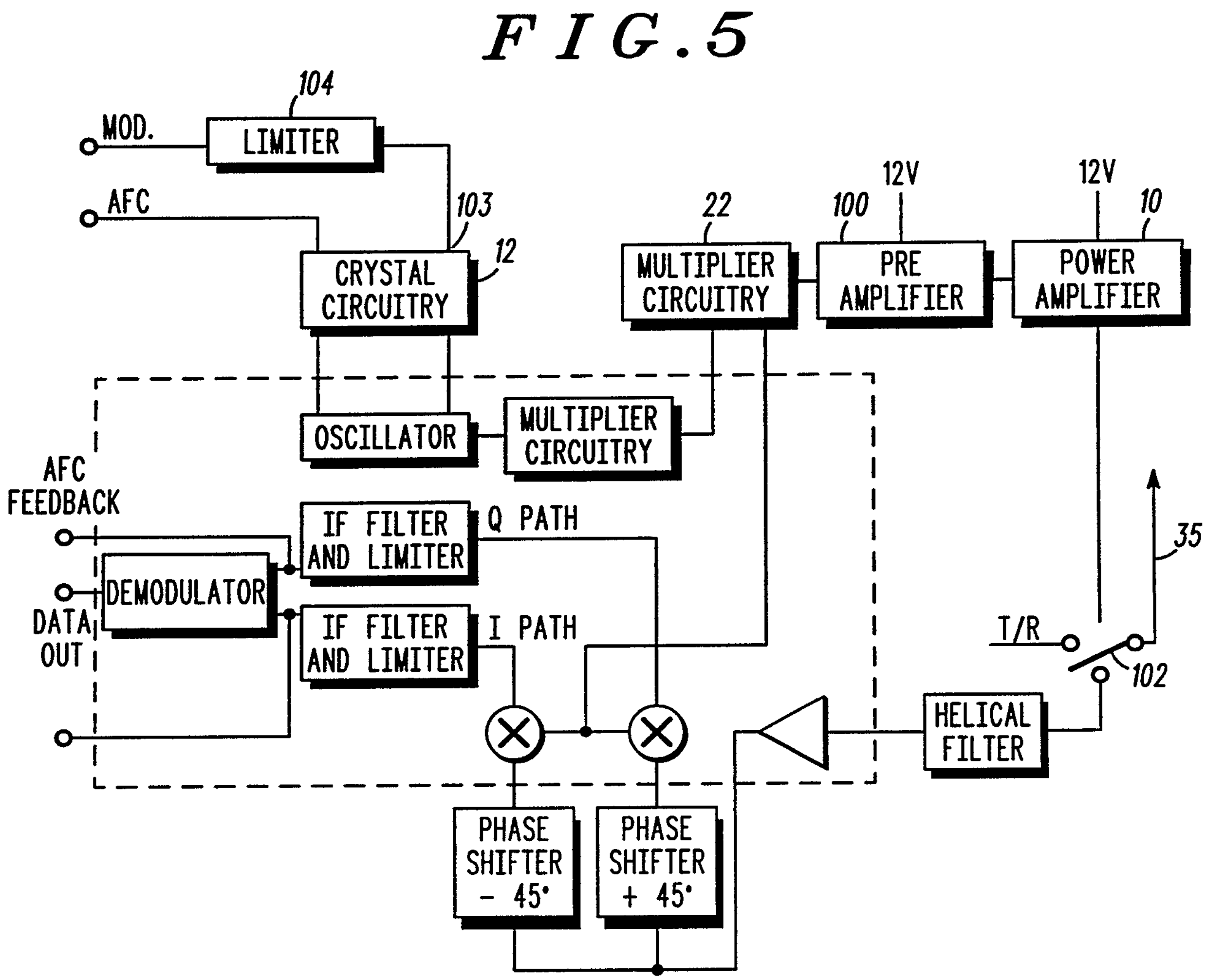


FIG.5
104
MOD.
LIMITER
AFC
103
12
CRYSTAL CIRCUITRY
OSCILLATOR
MULTIPLIER CIRCUITRY
22
MULTIPLIER CIRCUITRY
12V
100
PRE AMPLIFIER
12V
10
POWER AMPLIFIER
AFC FEEDBACK
IF FILTER AND LIMITER
Q PATH
DEMODULATOR
DATA OUT
IF FILTER AND LIMITER
I PATH
35
T/R
102
HELICAL FILTER
PHASE SHIFTER - 45°
PHASE SHIFTER + 45°

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A RADIO DEVICE AND A SINGLE-FREQUENCY RADIO TRANSPONDER

Field of the Invention

This invention relates to a radio device, such as a radio receiver or a radio transceiver and, separately and in addition, it relates to a single-frequency radio transponder.

Background to the Invention

Low cost direct conversion receivers are available in integrated form for use in paging receivers and the like. An example of an integrated direct conversion receiver is the UAA2080T advanced pager receiver manufactured by Philips Semiconductors. This particular direct conversion receiver is suited to frequency shift keying (FSK) data reception.

It is a problem in direct conversion and frequency modulation (FM) data receivers that the maximum data rate is limited by the frequency accuracy of a crystal oscillator used for providing a reference frequency for direct downconversion. For example, with 5KHz of frequency shift between opposite data stages in an FSK signal, and with 3KHz of potential frequency drift in a crystal oscillator, a resultant maximum data rate would be 2KHz. The frequency offset between the local oscillator and the carrier frequency effectively reduces the peak deviation and therefore the allowable data rate.

In superheterodine FM receivers, automatic frequency control is known which is implemented using a DC level out of a discriminator in the intermediate frequency stage. This is possible since the discriminator works at a low frequency at which the component tolerances become insignificant when translated up to the carrier frequency. Direct conversion receivers, however, do not have a low IF stage and the FM demodulation is performed at a baseband or audio frequency. With direct conversion receivers, a classic discriminator is not applicable and neither is an AFC method associated with it.

Summary of the Invention

According to the invention, a radio device is provided comprising: an adjustable reference oscillator for providing a reference frequency signal, a direct conversion receiver stage having an input and an output and means

for mixing a signal derived from the reference frequency signal with a radio frequency signal from the input, to directly convert said radio frequency signal to baseband at the output, and automatic frequency control means responsive to the output of the direct conversion receiver stage for detecting a potential frequency offset in the reference frequency signal from a predefined desired reference frequency and for adjusting the reference oscillator to more closely provide the reference frequency signal.

In accordance with the invention, automatic frequency control is employed in a direct conversion receiver, which has the advantage of improving the accuracy of the reference oscillator and thereby allowing a greater maximum data rate.

The baseband signal (down converted in the direct conversion receiver) is used to determine the frequency offset between the local oscillator's signal and the received frequency carrier.

In a particularly preferred embodiment, a radio receiver is provided comprising: a direct conversion receiver stage having an RF input for receiving at least RF modulated FSK data, in-phase and quadrature outputs and an adjustable reference oscillator; timing means for timing transitions of the in-phase output of the direct conversion receivers stage; comparator means for comparing successive periods between said transitions and control means for adjusting the reference oscillator when successive periods between transitions are of unequal duration.

FSK data is particularly convenient for detecting reference frequency drift, because when the reference frequency corresponds to the carrier centre of frequency, there should be no change of period in the in-phase samples with a change of data state. Other signals are, however, suitable for performing a measurement.

A synchronising pattern received from a transmitter may be used as the input signal for detecting the potential frequency offset.

In a further aspect of the invention, a single-frequency radio transponder is provided comprising: a direct conversion receiver circuit having a reference oscillator, a resonator for providing resonance for the reference oscillator and an automatic frequency control circuit for controlling the oscillator and resonator, means for modulating the resonator/oscillator, where in the oscillator provides a signal to an amplified element for amplifying a modulated output for transmission.

An advantage in this aspect of the invention is that the same oscillator and resonator and AFC circuit of a direct conversion receiver are

used for transmission. This is a particularly inexpensive solution for providing a transponder circuit, for example for pager acknowledgement or other data or control system, because a minimum of additional circuitry is necessary (no more than a vari cap diode for modulating the resonator/oscillator and a transistor for amplification).

It is particularly advantageous to provide an accurate reference oscillator in a transponder, because (a) regulating authorities require high stability in transmitted signals and (b) when a simple transponder receives and retransmits an FSK signal, the transmitted signal frequency has a tolerance which is the sum of the tolerance of the received signal and the reference oscillator. For example, if a received signal has 3KHz of offset from its intended centre frequency and it is retransmitted using a reference oscillator that is also 3KHz offset from its intended frequency, the potential total frequency in accuracy is 6KHz, which may be greater than the fixed frequency shift between data states, with the result that there is no frequency margin for transmission of data. This problem is overcome through the present invention.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the drawings.

Brief description of the drawings

Fig. 1 shows an overall block diagram of a radio receiver device in accordance with a first embodiment of the invention.

Fig. 2 shows details of the direct conversion stage of the receiver of Fig. 1.

Fig. 3 shows a time diagram of I, Q and recovered data outputs from the direct converter stage shown in Fig. 2 before automatic frequency control.

Fig. 4 shows the same signals as Fig. 3 after automatic frequency correction.

Fig. 5 shows a single frequency transponder in accordance with a second embodiment of the invention.

Detailed Description of the Preferred Embodiments

Referring to Fig. 1, a radio receiver device is shown comprising a direct conversion stage 10 (otherwise known as a zero IF receiver), having an RF input 11 and further comprising a crystal 12 a microcontroller 13 and a digital-analog converter (D/A) 14. The direct conversion zero IF receiver 10 has in-phase and quadrature outputs 15 and 16 and has a data output 17. These three outputs are shown as connected to the microcontroller, but for the purposes of the present invention, one, two or all three of these outputs may be utilised. The microcontroller 13 has an input capture circuit 50, a processor 51 and memory 52 which stores, among other information, a predetermined synchronization word.

In operation, a radio signal is input at input 11 and downconverted to a baseband frequency at output 17. Simultaneously, I and Q outputs are provided on outputs 15 and 16. These outputs are provided to microcontroller 13, which performs a measurement described below and provides a signal to D/A converter 14, causing D/A converter 14 to provide a frequency warp signal to crystal 12 for adjusting the crystal frequency, thereby achieving automatic frequency control for the direct conversion receiver 10.

Referring to Fig. 2, the direct conversion receiver 10 is illustrated in more detail. This receiver may, for example, be of the type UAA2080T manufactured by Philips Semiconductors. The circuit 10 comprises an oscillator 20 connected to the crystal circuitry 12, a first multiplier circuit 21, a second multiplier circuit 22, I and Q mixers 23 and 24, I and Q filters and limiters 25 and 26 and demodulator 27. Connected to the RF input 11 is an RF amplifier 28. Elements 20, 21 and 23 to 28 are shown as integrated within the direct converter receiver 10. Connected between the output of amplifier 28 and the mixers 22 and 24 are - 45° and + 45° phase shifters 30 and 31. These elements, together with multiplier of circuitry 22, are shown as being mounted external to the integrated circuit 10, but this is merely for the purpose of providing a universal design of circuit. These elements could equally be integrated into the same circuit. An antenna 35 is connected to the RF input 11. The crystal circuitry 12 has an automatic frequency control (AFC) or frequency warp input 18.

The direct conversion receiver consists of two quadrature down converters 23 and 24 producing two quadrature baseband signals I and Q. The FM detection is done by amplifying the baseband to a limit separately

phase shifting the signal into I and Q component signals and applying the two signals to a lead/lag phase detector.

The mathematical representation may be written as follows:

The received signal is: A cos $\{w_0 + \delta w) t\}$

where w_0 is the carrier angular frequency and δw is deviation. For simplicity assume that δw can have a value of either +dw or -dw.

After splitting in quadrature this gives:

I channel: A cos $\{(w_0 + \delta w) t\}$

Q channel: A sin $\{(w_0 + \delta w) t\}$

After mixing with the local oscillator signal from multiplier 22 this gives (for on-channel local oscillator):

I channel: A cos (δw^*t)

Q channel: A sin (δw^*t)

For a data state "1" this gives I: A cos (dw*t) and Q: A sin (dw*t). For a data state "0", it gives I:A cos(dw*t) and Q:-A sin(dw*t).

The frequency of the I and Q samples will therefore be dw regardless of the data state, if the local oscillator's signal is exactly on the carrier frequency.

Under the same conditions, the Q channel will have an output of + or - sin (dw*t) depending on the data state.

However, if there is a frequency offset between the local oscillator's signal and the carrier, there is effectively asymmetrical deviation, resulting in change of the frequency output between states.

For example, if logic "1" is denoted as positive deviation of +dw and logic "0" as -dw, a frequency offset of +e rad/sec at the local oscillator will cause the logic "1" to produce a frequency of dw-e at the I channel, while a logic "0" will produce a frequency of dw+e.

This is illustrated in Fig.3. In this figure, the received FSK signal is shown at the top of the figure and beneath this the I and Q samples and the recovered data. It can be seen that at a transition of the FSK signal from the higher frequency to the lower frequency, there is an increase in the period of the I samples. This represents a drop in the frequency of the I samples from dw + e to dw - e. There is, incidentally, also a drop in the period of the Q samples, but this drop is not apparent until the next cycle of the Q data. The recovered data follows from a falling edge in the I samples.

The microcontroller 13 measures from the input capture circuit 50 the time between transitions of the I signal. For example, it measures the time between a falling edge and a rising edge or between subsequent falling

edges. If the microcontroller 13 detects a change in the period of the I samples, this is indicative of an offset in the crystal oscillator frequency from the desired frequency. Upon detecting this offset, the microcontroller can proceed in a number of alternative processes. In one example, it calculates the difference in frequency in the I samples at the transition and, from this (and from the multiplier factors of the multiplier circuitry 21 and 22) it calculates the necessary frequency warp signal to be supplied to the crystal oscillator to correct the crystal oscillator frequency. Without further information, however, the microcontroller is not able to determine whether an increase or decrease in the crystal oscillator frequency is necessary. In the first alternative embodiment, the microcontroller attempts an outset in one direction, for example an increase, and monitors whether the frequency has been corrected. If the frequency of the local oscillator has been corrected, the signal shown in Fig. 4 will be received. In Fig. 4, the I samples have a regular periodicity. If the frequency offset has not been corrected, the difference in period in the I samples at the data transition will increase further and the microcontroller 13 is then able to confirm that the opposite frequency correction is required.

In an alternative embodiment, the microcontroller 13 receives from the data output 17 a predetermined data sequence, for example a synchronisation word pre-stored in memory 52. With prior knowledge of the incoming data stream, the microcontroller is able to determine whether the change in period of the I samples is occurring at a transition from "1" to "0" or from "0" to "1" and is able to compute the direction of change of the crystal oscillator frequency that is required.

Thus the frequency at the I channel in both logic states is measured and it is a simple matter tuning the frequency of the local oscillator to provide the same frequency at both states. This is a very accurate procedure since it is not necessary to make any assumption other than that the incoming deviation should be symmetrical about the carrier frequency.

With prior knowledge of the logic state, it is possible to determine the direction of the required frequency correction. That is, if the frequency measured during the "1" state is lower than the frequency measured during the "0" state, the local oscillator frequency is evidently too high, and vice versa.

The circuit shown requires no additional parts, since in most receivers of this nature a microcontroller is present for data processing. The

measurement is highly accurate, since baseband signal is used, so that any error has little effect when translated to the carrier.

Naturally, the same principles apply for using the Q channel output for measurement.

The above description has been given in the case of an input FSK signal but it is not essential that such a signal is used, other signals, such as a PSK signal can be used, but the measurement performed by the microcontroller, must be adapted to the nature of the received signal.

Referring now to Fig.5, it is shown how the above circuitry can advantageously be used in an inexpensive and simple single frequency transponder. In addition to the element shown in Fig.2, the single frequency transponder has a pre-amplifier 100 connected to the multiplier circuitry 22 and a power amplifier 101 connected to the pre-amplifier 100 and to the antenna 35 by an optional transmit/receive switch 102. The crystal circuitry 12 has an additional modulator input 103, receiving a signal from the microcontroller 13 via an optional limiter 104.

In its simplest form, the additional circuitry necessary to make the circuit of Fig. 2 into a single frequency transponder comprises no more than a transistor performing the function of pre-amplifier 100 and power amplifier 101 and a line from the microprocessor 13 to the crystal oscillator circuitry 12. Other elements of the receiver circuitry are reused for the transmitter. These are the oscillator 20, the multiplier circuitry 21 and 22 and the crystal circuitry 12.

In operation, a signal is received as described above and automatic frequency control is used to correct the frequency provided by the crystal circuitry 12. when the microcontroller 13 wishes to transmit, it provides a modulation signal on a modulating input 103 of the crystal circuitry 12 and opens the power amplifier 101 (or switches the switch 102), allowing the signal generated by the oscillator 20 and multiplied by the multiplier circuitry 21 and 22, to be transmitted through the antenna 35.

Since the local oscillator and the transmitter exciter are the same oscillator, there is a saving in parts count and circuit complexity. Since there is no change of frequency of the oscillator from transmit to receive, the switching time is reduced to the rise time of the carrier in the amplifier and the antenna switch response time.

The arrangement described is highly suitable for applications such as pager acknowledgement, or for acknowledgement in a supervisory control and acquisition of data (SCADA) system. Thus, for example, the receiver 10

could be used to control a sprinkler valve of an irrigation system and the transmitter portion can be used to transmit a simple acknowledgement to confirm that the receiver has received an instruction correctly and operated the sprinkler valve. The circuit is particularly suitable for low power operation, where the acknowledgement signal will be received at a receiver located nearby.

Claim

1 A radio device comprising:

an adjustable reference oscillator (12) for providing a reference frequency signal,

a direct conversion receiver stage (10) having an input (11) and an output (15, 16, 17) and means for mixing a signal derived from the reference frequency signal with a radio frequency signal from the input, to directly convert said radio frequency signal to baseband at the output, and

automatic frequency control means (13, 14, 18) responsive to the output of the direct conversion receiver stage for detecting a potential frequency offset in the reference frequency signal from a predefined desired reference frequency and for adjusting the reference oscillator to more closely provide the reference frequency signal.

2. A radio receiver comprising:
a direct conversion receiver stage (10) having:

an r.f. input (11) for receiving at least r.f. modulated data,

in-phase and quadrature outputs (15, 16) and

an adjustable reference oscillator (12);

timing means (50) for timing transitions of at least one of the outputs of the direct conversion receiver stage;

processor means (51) for comparing successive periods between said transitions and for adjusting the reference oscillator when successive periods between transitions are of unequal duration.

3. A radio receiver according to claim 2, further comprising memory means for pre-storing a sequence of data states,

wherein the processor means (51) are arranged to relate transitions of the at least one output of the direct conversion receiver stage to data states of the pre-stored sequence of data states and to calculate a required adjustment for the reference oscillator from the durations of successive periods between transitions so related.

4. A radio receiver according to claim 2, wherein the processor means are arranged to calculate an estimated adjustment for the reference oscillator from the durations of successive periods between transitions of the at least one input, to implement said estimated adjustment, to monitor the

effect of said estimated adjustment and to calculate a corrected adjustment if the implemented adjustment is found not to be correct.

5. A single-frequency radio transponder comprising:

a direct conversion receiver circuit (10) having an oscillator (20)

a resonator (12) for providing resonance for the oscillator and

an automatic frequency control circuit (13, 14, 18) for controlling the oscillator and resonator,

means (103) for modulating the resonator, and

an amplifier element (101) coupled to the oscillator for amplifying a modulated output for transmission.

6. A transponder according to claim 5, further comprising a multiplier circuit (21, 22) for multiplying the oscillator signal to a required r.f. signal.

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Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

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Relevant Technical Fields

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(ii) Int Cl (Ed.5) H03L, H03D, H04L

Search Examiner
MR S SATKURUNATH

Date of completion of Search
26 MAY 1994

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASES: WPI, EDOC

Documents considered relevant following a search in respect of Claims :-
1-6

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2213663 A	(PHILIPS) see especially Figure 1	1
X	GB 2191367 A	(RCA) see especially Figures 1, 2	1
X	GB 2017436 A	(SOCIETE) see especially Figure 3	1

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).